

Latent Heating Retrievals Deriving from TRMM

Overview (Status)

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- Latent Heating and Heating Algorithms - November 2006 BAMS and 2007 *Mon. Wea. Rev.*
- Current products
- Recent Applications
- Intercomparison-validation project
- Workshops' recommendations - 2007 BAMS
- Suggestions/Inputs

Tao, W.-K., E. Smith, R. Adler, Z. Haddad, A. Hou, T. Iguchi, R. Kakar, T.N. Krishnamurti, C. Kummerow, S. Lang, R. Meneghini, N. Nakamura, T. Nakazawa, K. Okamoto, W. Olson, S. Satoh, S. Shige, J. Simpson, Y. Takayabu, G. Tripoli, and S. Yang, 2006: Retrieval of latent heating from TRMM measurements, *Bull. Amer. Meteor. Soc.*, (November issue).

Tao, W.-K., E. Smith, A. Hou, S. Lang, W. Olson, S. Satoh, S. Shige, Y. Takayabu, and S. Yang, 2007: Latent heating from TRMM satellite measurements: Algorithm Description, Validation methodology and Application. *Mon. Wea. Rev.* (to be submitted).

Tao, W.-K., R. Houze, Jr., and E. Smith, 2007: Summary of the 4th TRMM Latent Heating Workshop, *Bull. Amer. Meteor. Soc.*, (submitted).

E. Stocker/J. Kwiatkowski
R. Johnson/P. Ciesielski (CSU), R. Houze (U. Wash), M.H. Zhang (SUNY)

CRM Simulated Q₁ Budget

$$Q_1 - Q_R = \bar{\pi} \left[-\frac{1}{\bar{\rho}} \frac{\partial \bar{\rho} w' \theta'}{\partial z} - \bar{V}' \cdot \nabla \theta' \right] + \frac{L_v}{C_P} (c - e) + \frac{L_f}{C_P} (f - m) + \frac{L_s}{C_P} (d - s)$$

LH: Latent Heat - phase change of water

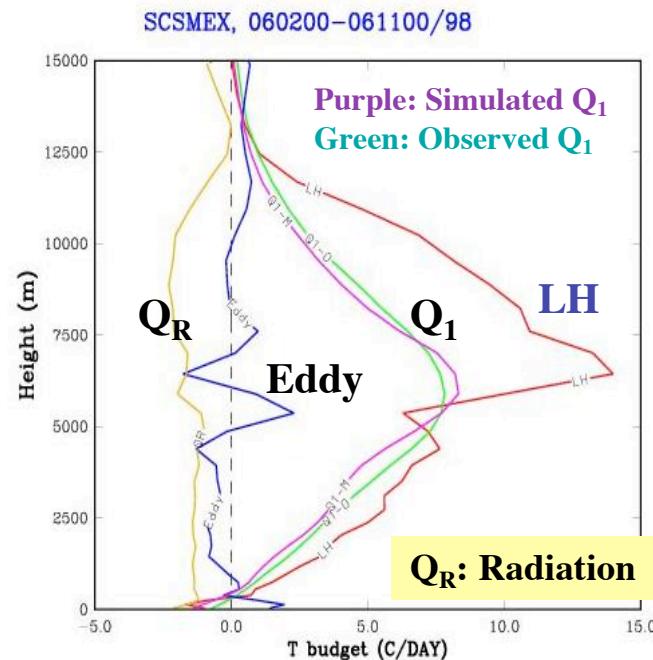
Eddy - heat transport by cloud dynamics

$$\frac{1}{g} \int_{Lx} \int_{P_{top}}^{P_{base}} (Q_1 - Q_R) \Delta p \Delta x = LP_o + S_o$$

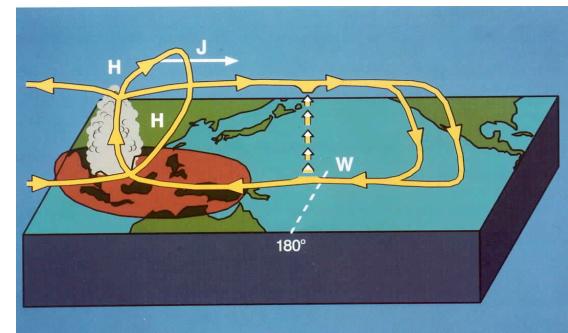
Rainfall + Sensible heat fluxes

Sounding Estimated Q₁ Budget

$$Q_1 = \bar{\pi} \left[\frac{\partial \bar{\theta}}{\partial t} + \bar{V} \cdot \nabla \bar{\theta} + \bar{w} \frac{\partial \bar{\theta}}{\partial z} \right]$$



- LH is the primary energy to drive atmospheric circulation.**
- Convection plays a major role in tropical intra-seasonal variability and quasi-stationary circulation/ITCZ/MJO**
- Improvement/validation of cumulus parameterization in GCMs and Climate models.**



Latent Heating Algorithms

Convective - Stratiform Heating - CSH (Tao/Lang et al. 1993, 2000)

PR or TMI (Cloud model generated look-up table)

Spectral Latent Heating - SLH (Shige/Takayabu et al. 2003, 2006)

PR (Cloud model generated look-up table)

Hydrometeor Heating - HH (Yang/Smith et al. 1999)

PR or PR/TMI Combined (Hydrometeor mass conservation)

Goddard Profiling - GPROF (Olson et al. 1999, 2006)

TMI or Combined (Cloud model generated look-up table)

Precipitation Radar Heating - PRH (Satoh/Noda 2001)

PR (Hydrometeor mass conservation)

Tao, W.-K., E. Smith, R. Adler, Z. Haddad, A. Hou, T. Iguchi, R. Kakar, T.N. Krishnamurti, C. Kummerow, S. Lang, R. Meneghini, N. Nakamura, T. Nakazawa, K. Okamoto, W. Olson, S. Satoh, S. Shige, J. Simpson, Y. Takayabu, G. Tripoli, and S. Yang, 2006: Retrieval of latent heating from TRMM measurements, *Bull. Amer. Meteor. Soc.*, (November issue).

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Current Products Available in TSDIS (Experimental)

CSH (3A25 - PR) - 0.5 x 0.5 degree, Monthly

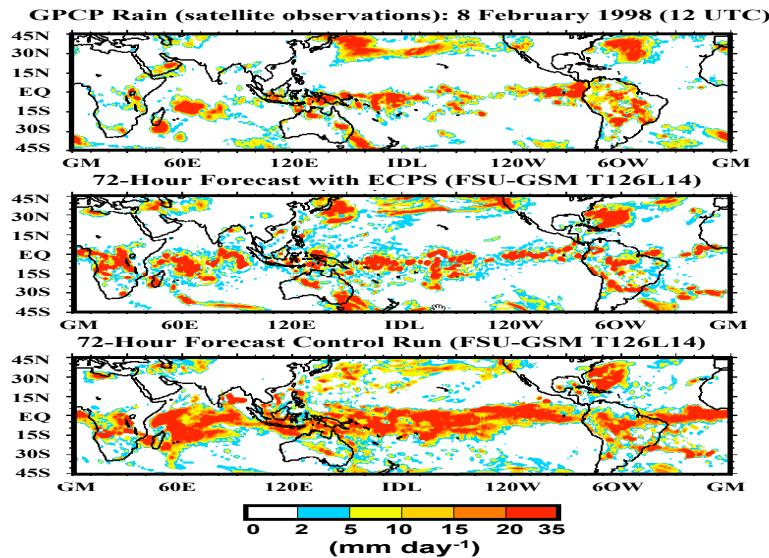
GPROF (2A12 - TMI) - Orbital, Instantaneous

HH (2B31 - Combined) - Orbital, Instantaneous

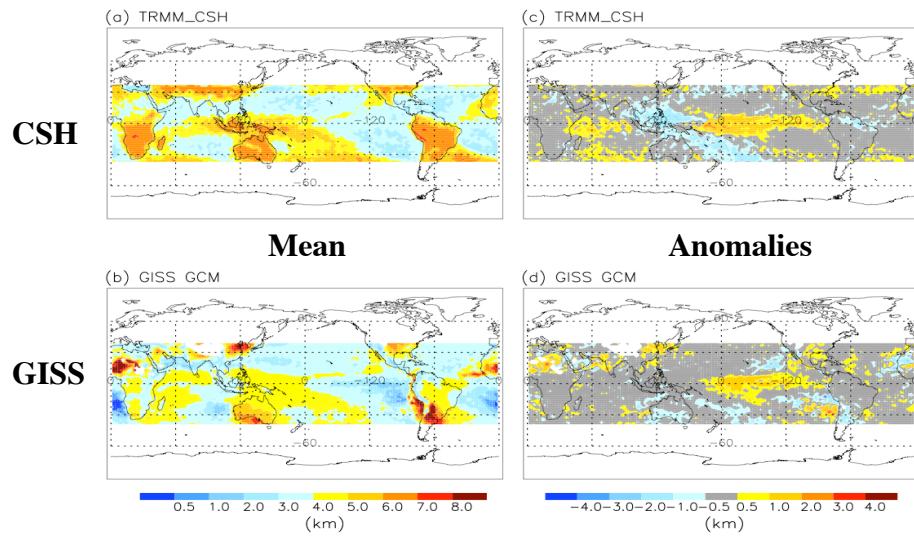
Latent Heating Products (Beta - V1 in 2007)

0.5 x 0.5 degree from daily - weekly - seasonal
Convective and Stratiform region
Regimes (e.g., African Monsoon)

(a) LH Experiment 1

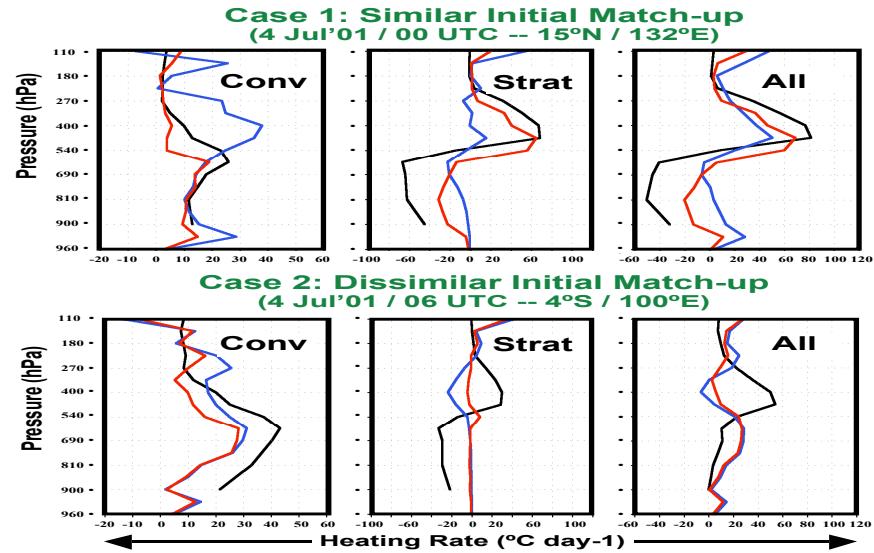


Improve 72 h forecast -Rajendran *et al.* (2004, *J. Meteor. Soc. Japan*)



Mean and ENSO 1998 DJF anomalies in the altitude of peak latent heating for the CSH product and the GCM. Chen, Del Genio, Chen (2006, *J. Climate*)

(b) LH Experiment 2



Two contrasting examples of predicting Q_1 heating profiles by assimilating convective and stratiform TMI retrievals. Hou and Zhang (2006, JAS)

Recent Applications

Improve NWP (Rajendran *et al.* 2004).
Validate Climate Model (Chen, Del Genio, Chen, 2006).
Assimilate Q_1 heating profiles into Global Model (Hou and Zhang 2006).

TRMM Latent Heating Workshops

- ***1st Workshop:*** NASA Goddard Space Flight Center Greenbelt, May **10-11** 2001 (**W. Olson, R. Johnson and W.-K. Tao**) 18 participants
- ***2nd Workshop:*** NCAR Boulder CO, October **10-11** 2001 (**M. Moncrieff, A. Hou and W.-K. Tao**) ~ 30 participants after 9.11
- ***3rd Workshop:*** Nara Japan, September **10-11** 2004 (**E. Smith, S. Shige and W.-K. Tao**) 20 participants

Conduct TRMM Latent Heating Comparison - Validation using V6 rain products

1st Meeting: Tokyo, Japan, November 10 2005 (3rd International GPM Workshop)

2nd Meeting: Monterey, California, USA, December 15 2005 (NASA PMM Science Meeting)

- ***4th Workshop:*** Seattle Washington, May 17-19 2006 (**R. Houze, E. Smith and W.-K. Tao**) 26 participants
- ***5th Workshop (Spring 2007)***

Workshop Objectives

- to discuss validation issues, particularly the diagnostic analyses used for validation
- to discuss further requirements and applications issues
- to define standard latent heating products
- to identify future data products and analyses that may be required in the future for the GPM (the major objective - 5th Workshop)

TRMM Latent Heating Intercomparison - Validation Project

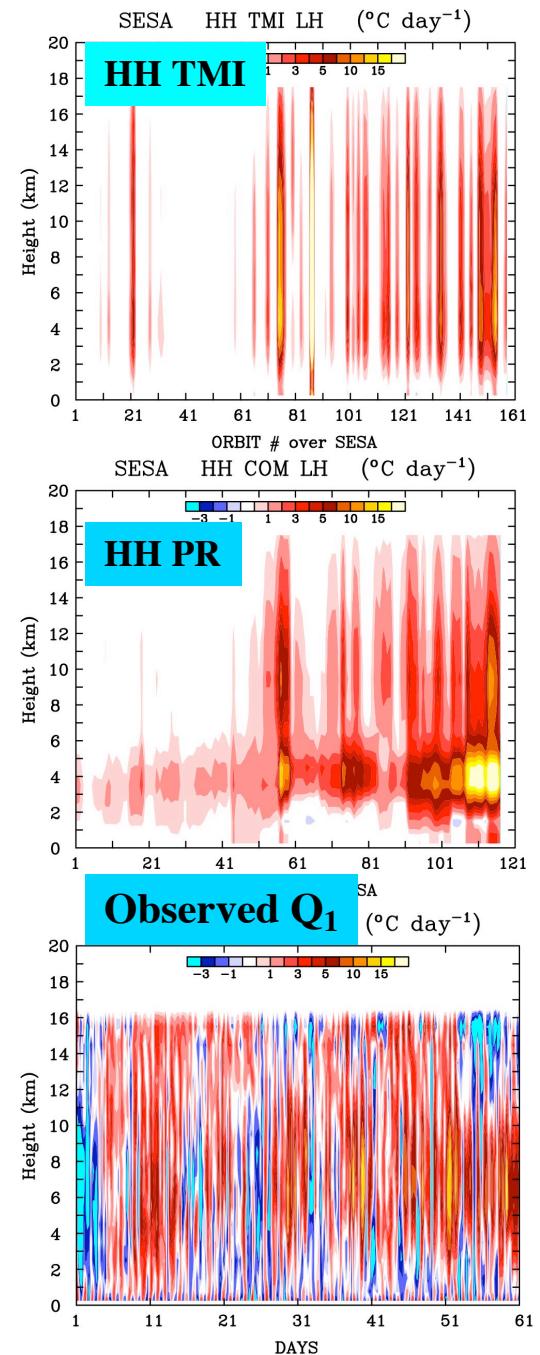
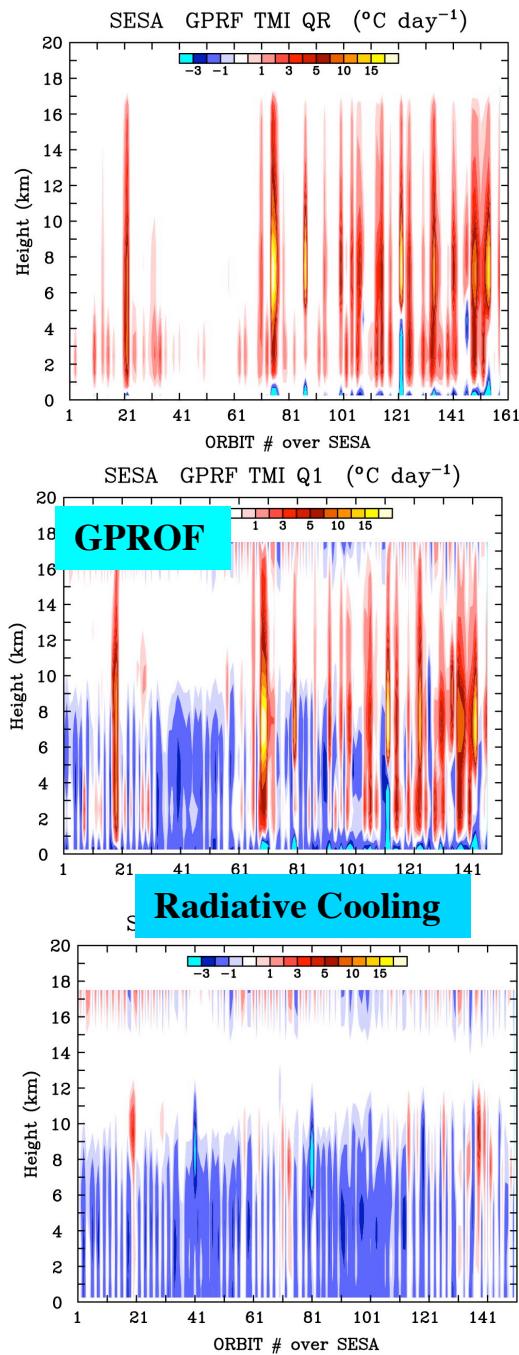
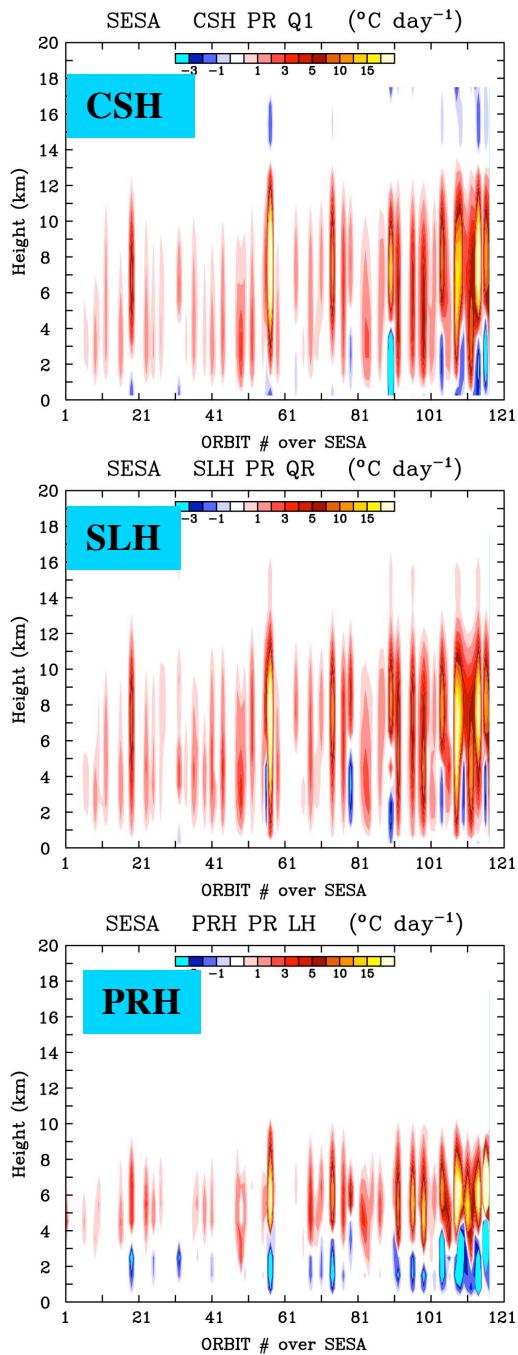
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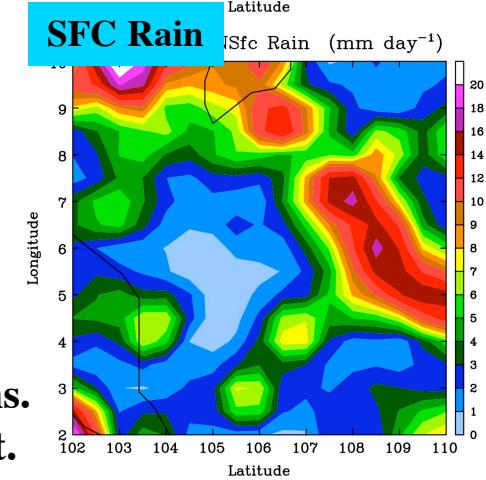
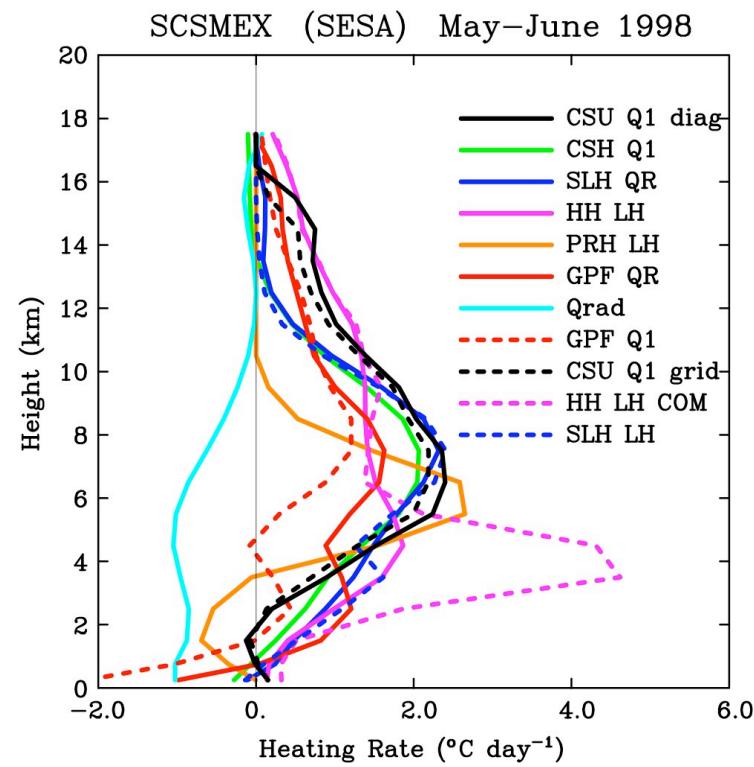
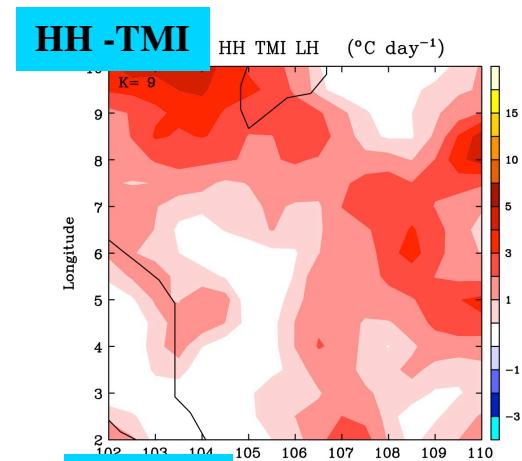
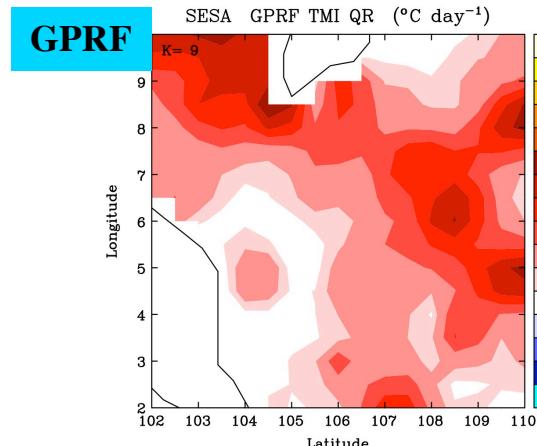
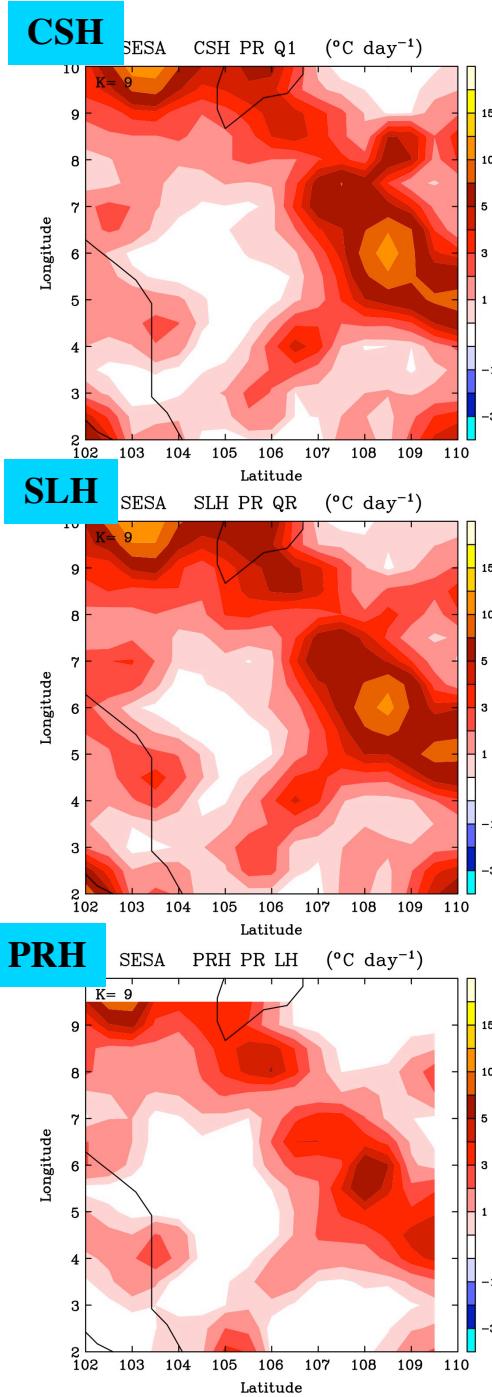
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- SCSMEX (May 1 - June 30 1998)
- TRMM LBA (January 24 - February 28 1999)
- KWAJEX (July 24 - September 14 1999)
- DOE/ARM (March 1 - March 22 2000, May 25 - June 15 2002)
- Hurricane Bonnie (August 22 1998)
- Typhoon Jelawat (August 2 2000)
- Tropical Rainforest (December 97 - December 2000, 20° S - 20° N, 70°W - 35° W)
- Tropical Ocean (December 97 - December 2000, 20° S - 20° N, 160° E - 90° W)

SCSMEX (SESA)

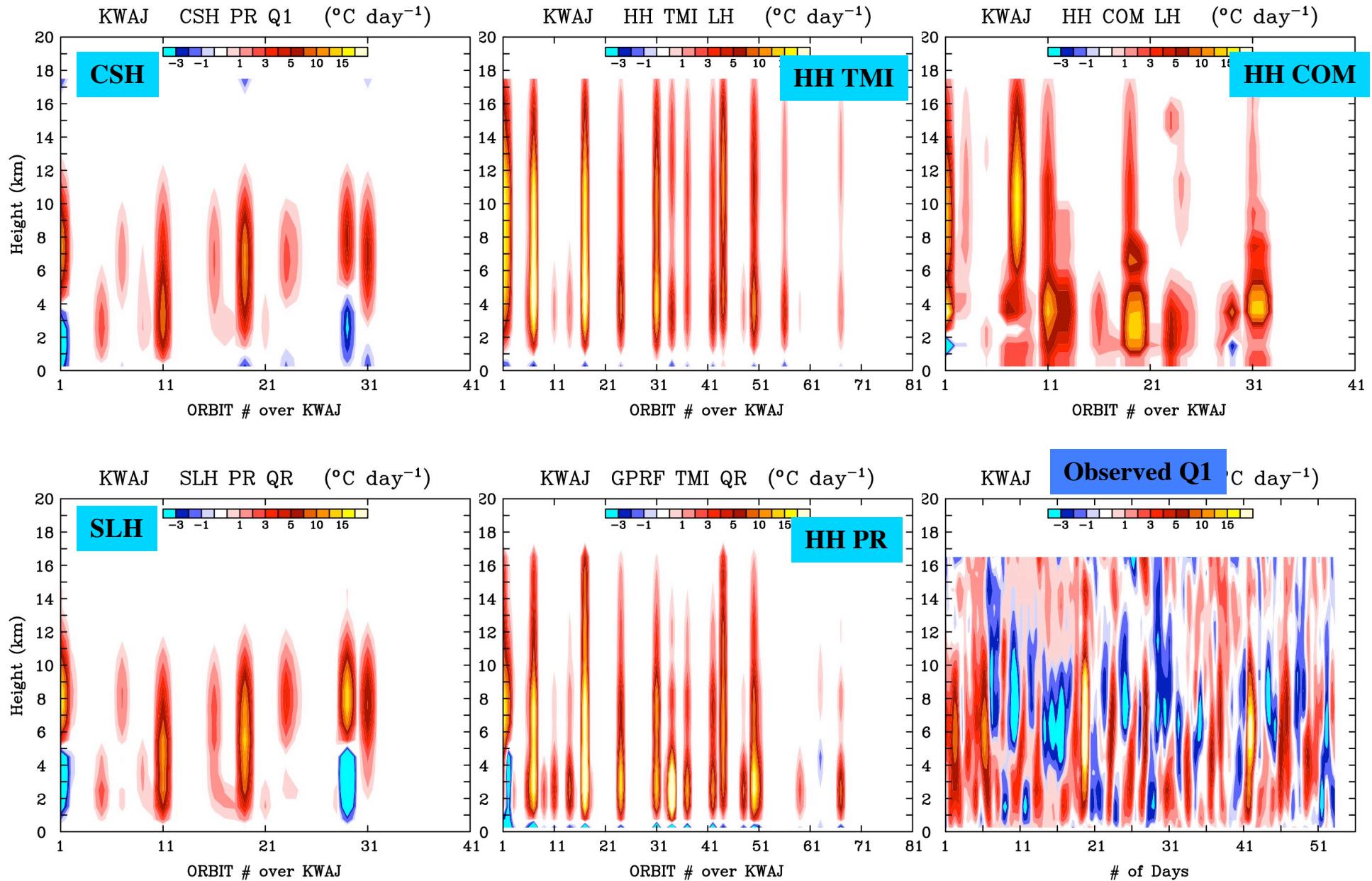


SCSMEX (SESA)



**Retrieved Mean Q_1 from heating algorithms.
Estimated Mean Q_1 from diagnostic budget.**

KWAJEX



Summary (Preliminary) (SCSMEX, KWAJEX, ARM and LBA)

- CSH & SLH similar for all four cases
- Algorithms similar aloft, variable at low levels
- Sampling issues (e.g., PR does not fully cover KWAJEX, LBA and ARM domain)
- Algorithms match observations for some case but not others

4th TRMM Latent Heating Workshop

Action Items

- Group--Consolidate (without merging) SLH & CSH
- Group--Consolidate (without merging) HH & PRH
- GPROF final decisions in regard to V7
- Explore the relationship between latent and radiative heating
- Produce cases 7 & 8 data sets at GSFC for reprocessing
- **Validate Case 1-4 (Resolve the sampling issue)**
- Submit papers on intercomparison
- **Recommend to TSDIS to produce Beta version (launch to present)**
- ***Solicit input from GEWEX (Emissary)- January 2007***
- ***Participate in ARM radiative heating profile workshop - January 2007***
- ***Report to GV study team***
- ***Solicit input from large-scale modeling groups*** (major objective for 5th TRMM latent heating workshop)

Tao, W.-K., R. Houze, Jr., and E. Smith, 2007: *Summary of the 4th TRMM Latent Heating Workshop, Bull. Amer. Meteor. Soc.*, (submitted).

Inputs